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RESEARCH DEPARTMENT

SPECIFICATION OF THE IMPEDANCE OF TRANSMITTING AERIALS FOR MONOCHROME AND COLOUR TELEVISION SIGNALS

Technological Report No. E-115
(1965/8)

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for Head of Research Department

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SPECIFICATION OF THE IMPEDANCE OF TRANSMITTING AERIALS FOR MONOCHROME AND COLOUR TELEVISION SIGNALS

SUMMARY

Any departure of the impedance of a television transmitting aerial from the characteristic impedance of its feeder results in the transmission of delayed signals. This report specifies the maximum departures of impedance that are permissible without visible distortion for 405-line and 625-line monochrome and colour television signals. The specifications for monochrome signals are derived from the results of earlier work; those for colour signals are derived from the results of a recent investigation. The specifications are given in terms of the permissible level of delayed signal that may be radiated; by allowing for feeder and other losses, they may be used to frame an impedance specification for a particular aerial installation.

The specifications are framed with a view to meeting the requirements with the least engineering difficulty.

1. INTRODUCTION

In order to radiate undistorted signals, the impedance of a television transmitting aerial must be closely matched to the characteristic impedance of the feeder which connects it to the transmitter. If the impedance of the aerial is different from that of the feeder, signals are reflected back to the transmitter where they undergo a second reflexion and are radiated with a delay due to the two additional traversals along the feeder. If the feeder is very short the resulting distortion is manifest as an incorrect amplitude and phase characteristic over the frequency band. If the feeder is very long a discrete delayed image (frequently termed 'ghost' image) is visible on the receiver display.

The limits that must be imposed on the aerial impedance characteristic are governed by the perception of the human eye. Some years ago a series of subjective tests was carried out for the 405-line monochrome system;[1] those tests led to specifications for impedance characteristics that could be met with the least engineering difficulty. This report summarizes those specifications, extends them for application to the present 625-line monochrome system, and describes a further series of subjective tests that has been performed in collaboration with Television Group of Research Department in order to frame impedance specifications suitable for possible future 625-line colour systems.

2. 405-LINE MONOCHROME SYSTEM

2.1. Short-delay Reflexions

In 1948/9 subjective tests were carried out by the Post Office,[2] in collaboration with the BBC, to determine the permissible limits of distortion for 405-line television pictures. Using delays from 0·25 μs to 2·0 μs, relative levels of an undistorted delayed image (e.g. one due to a reflexion coefficient independent of frequency) were determined such that the resulting distortion was invisible to 50% of the observers. The results showed that the visibility of the delayed image increased with delay-time up to about 1 μs and thereafter remained constant.

Later work has shown, however, that levels of delayed signal which were judged acceptable in 1949 would, using present-day equipment, give noticeable distortion; this is presumably because the cameras used in 1949 had a poor high-frequency response. Laboratory tests simulating ideal equipment[1] have shown that, for the distortion to be imperceptible to 50% of experienced viewers,* the relative levels of delayed signal should not exceed the values given in Table 1.

TABLE 1

TIME DELAY (μs)	$\frac{\text{DELAYED SIGNAL}}{\text{PRIMARY SIGNAL}}$ (dB)
0·25	-26
0·5	-32
1·0	-38
2·0	-38

2.2. Long-delay Reflexions

Levels of delayed signal permissible on the 405-line monochrome system are specified in Research Department Report No. E-046.[1] One specification, shown as curve (*a*) in Fig. 1, requires the relative amplitude of a signal delayed by at least 1 μs to be not greater than 1·25% over the bandwidth of the lower sideband and permits it to rise linearly with frequency to not more than 2·5% at the limit of the upper (vestigial) sideband. In Fig. 1 the frequency scale is reversed for comparison with the later figures. A second specification, which is more generally adopted, is shown as curve (*c*) in Fig. 1; this requires the relative amplitude of the delayed signal to be not greater than 0·7% at the vision carrier frequency but permits it to increase linearly with frequency to not more than 5·6% at the limit of the lower sideband and to not more than 4% at the limit of the upper sideband. An intermediate specification is reproduced as curve (*b*) in Fig. 1.

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* By an experienced viewer is meant one experienced in detecting faults in television picture displays. See also Section 4.3.2.

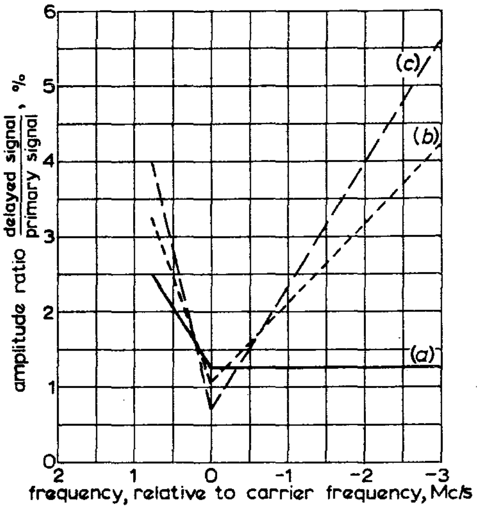

Fig. 1 - Percentage delayed signal: 405-line monochrome system

(*a*) 'Flat' characteristic
(*b*) '12 dB top-lift' characteristic
(*c*) '18 dB top-lift' characteristic

3. 625-LINE MONOCHROME SYSTEM

3.1. Application of 405-line Results

As shown in Table 1, the perceptibility of a delayed image depends upon both its amplitude and its horizontal separation from the primary image. For a given delay, this horizontal separation is defined by the active line-period; results obtained for the 405-line monochrome system (for which the active line-period is 80·7 μs) can consequently be applied to other monochrome systems provided their active line-periods are known. Thus for the 625-line system (with active line-period 52 μs) a given horizontal separation (and hence a given perceptibility) between primary and delayed images is caused by 52/80·7 or 0·645 times the delay required for the 405-line system.

3.2. Short-delay Reflexions

The argument of Section 3.1 applied to the results of Table 1 gives close agreement with results obtained using delays of 0·2 μs and 2·0 μs on the 625-line monochrome system.[3] Those results, together with the results of Table 1 multiplied by the line-period ratio (0·645 times), are specified in Table 2.

TABLE 2

TIME DELAY (μs)	DELAYED SIGNAL / PRIMARY SIGNAL (dB)
0·16	-26
0·20	-29
0·32	-32
0·65	-38
1·3	-38
2·0	-38

Table 2 shows that the visibility of a delayed image on the 625-line system increases with delay time up to about 0·6 μs and thereafter remains constant. Signals delayed by more than 0·6 μs should therefore be regarded as long-delay signals and dealt with as described in the next section.

3.3. Long-delay Reflexions

It follows from the argument of Section 3.1 that a given horizontal detail on the picture tube occurs at modulation frequencies on the 625-line system which are 1/0·645 or 1·55 times higher than on the 405-line system. The specifications applicable to the 405-line system (for delays greater than 1 μs) shown in Fig. 1 can therefore be made to apply to the 625-line monochrome system (for delays greater than 0·6 μs) by multiplying the frequency scales by 1·55.

The resulting specifications are shown in Fig. 2.

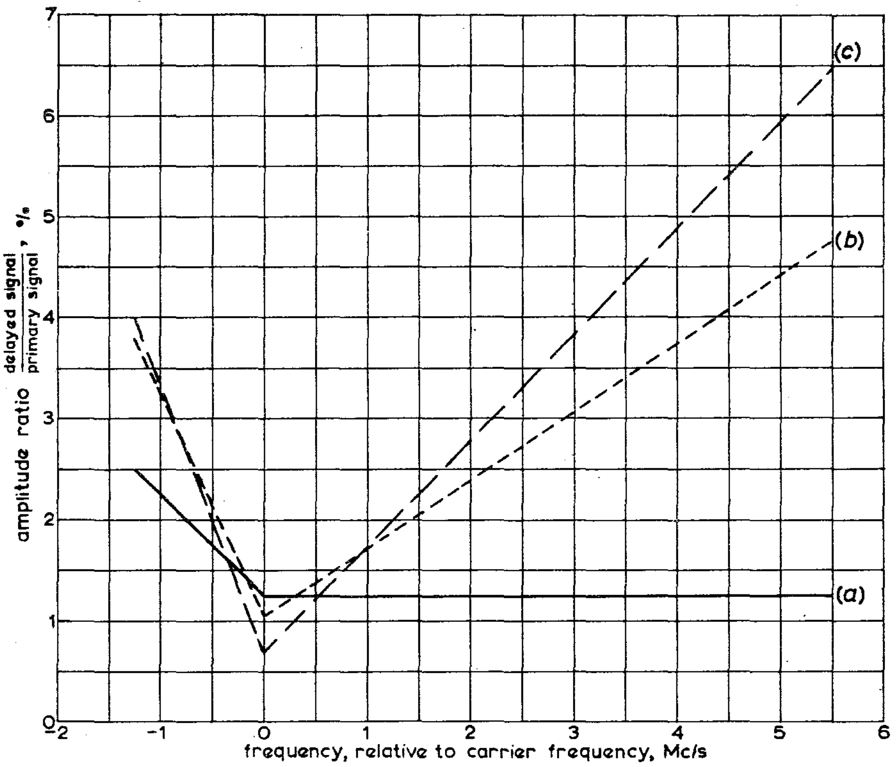

Fig. 2 - Percentage delayed signal: 625-line monochrome system

(*a*) 'Flat' characteristic
(*b*) '12 dB top-lift' characteristic
(*c*) '18 dB top-lift' characteristic

4. 625-LINE COLOUR SYSTEM

4.1. General

No standard has yet been adopted for colour television transmissions in the United Kingdom but the three systems at present under consideration (designated NTSC, SECAM and PAL) use a luminance signal transmitted as the amplitude modulation of the picture carrier together with chrominance signals transmitted as the modulation of a sub-carrier, the frequency of which is approximately 4·43 Mc/s higher than that of the picture carrier. The presence of a delayed signal on such systems not only causes errors of brightness due to interference with the luminance signals (as for monochrome transmissions) but also errors of hue and saturation due to interference with the chrominance signals.

The following remarks (Sections 4.2 and 4.3) have been found to apply to colour signals of the NTSC type; signals coded according to the standards of PAL or SECAM are likely to be slightly less demanding, but not sufficiently to affect the ultimate impedance specifications.

4.2. Short-delay Reflexions

The effect of a short-delay reflexion is to modify the high-frequency response of the radiated signal rather than to produce a secondary image. Colour signals are likely to be less tolerant than monochrome in that respect; this is because on monochrome the effect is slightly to enhance or degrade the fine picture detail, whereas on a colour transmission the effect is to change the colour saturation, and this is much more noticeable.

The American NTSC tolerances on the transmitted chrominance signal are 10° in phase and 20% in amplitude. The overall tolerances proposed in Report No. 33 of the London (1964) meeting of Study Group XI of the CCIR[4] are 12° in phase and 33% in amplitude; these correspond to a subjective grade between 'just perceptible' and 'definitely perceptible but not disturbing'. Bearing these tolerances in mind, and also that other parts of the transmission system will contribute to this type of distortion, it seems reasonable to assign to the aerial errors of not more than 2° in phase or 4% in amplitude; this corresponds to a delayed-signal amplitude of 3·5%, i.e. -29 dB relative to the primary signal.

For colour transmissions, therefore, the requirements of Table 2 should be satisfied but with the further condition that the reflected signal should not exceed -29 dB, relative to the primary signal, however short the delay.

4.3. Long-delay Reflexions

4.3.1. General

The 'flat' specification (i.e. a reflexion coefficient independent of frequency over the upper sideband) for a 625-line monochrome system (Fig. 2) applies equally to a 625-line colour system; the relaxations that can be allowed in the monochrome case at frequencies removed from the picture carrier, however, cause noticeable interference with the chrominance signals associated with colour transmissions. Since those relaxations usually simplify aerial designs, it was desirable to determine to what degree they may be allowed on an aerial radiating colour signals. Accordingly, the following subjective tests were performed.

4.3.2. Subjective Tests

To reduce instrumental complication, the tests were performed using a video-frequency analogue (shown block-schematically in Fig. 3) of a perfect double-sideband

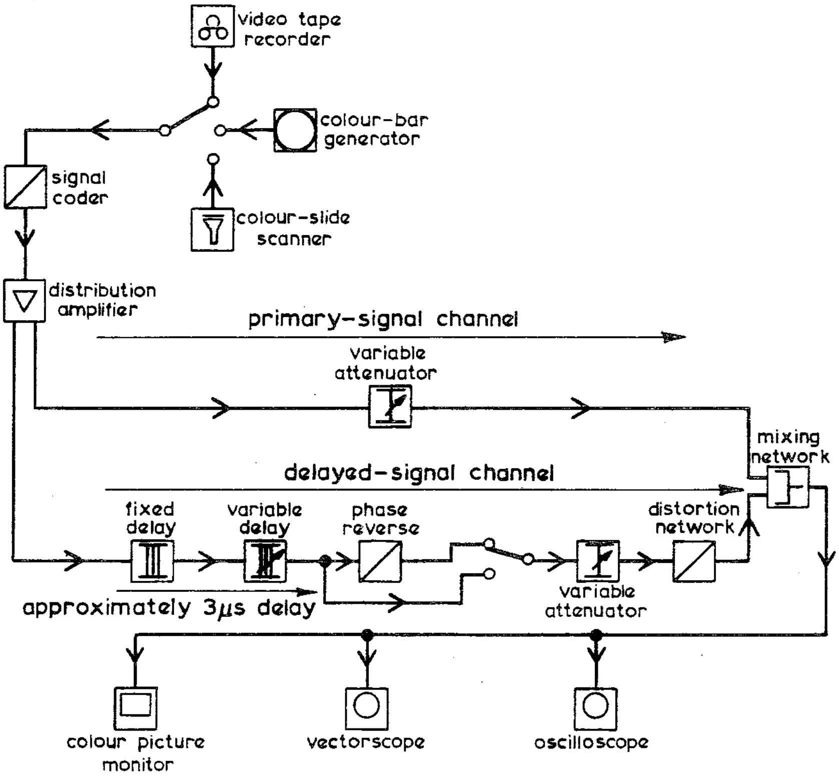

Fig. 3 - General arrangement of equipment

system. In a carrier system, the relative phases of the primary and delayed signals at the luminance and chrominance carrier frequencies affect the visibility of the delayed signals. At the luminance carrier frequency the worst conditions occur when the delayed signal is either in phase or in anti-phase with the primary signal and either of these two conditions could be reproduced by the analogue. Any phase relationship between the signals at the chrominance carrier frequency could be reproduced by making a small adjustment to the delay. The analogue is therefore applicable to double-sideband monochrome or colour systems. Furthermore, as discussed in detail for the previous tests using monochrome signals,[1] the visibility of a delayed signal in the case of vestigial-sideband reception will not exceed that occurring in the double-sideband case. Results obtained using the video analogue may therefore be applied to double-sideband or vestigial-sideband monochrome or colour systems.

For the tests, pictures displayed on a high-quality colour monitor were judged by a panel of four or five engineers experienced in detecting faults in television picture displays. Experienced engineers were chosen in order to set a standard that would satisfy the most critical viewers.

As shown in Fig. 3, the output from either a colour-bar generator, a slide scanner, or a video tape recorder was coded in accordance with an NTSC-type signal specification, shared between a primary-signal and a delayed-signal channel and re-combined at the input of a high-quality picture monitor fitted with a 21 in. shadowmask tube. In the delayed-signal channel, a 3 μs delay line was connected in cascade with a distortion network which simulated the aerial characteristic under test. Provision was made to phase-reverse the delayed signal and, by adjusting a small variable delay, to achieve any desired phase relationship (indicated on a 'vectorscope') between the signals from the two channels at the chrominance carrier frequency.

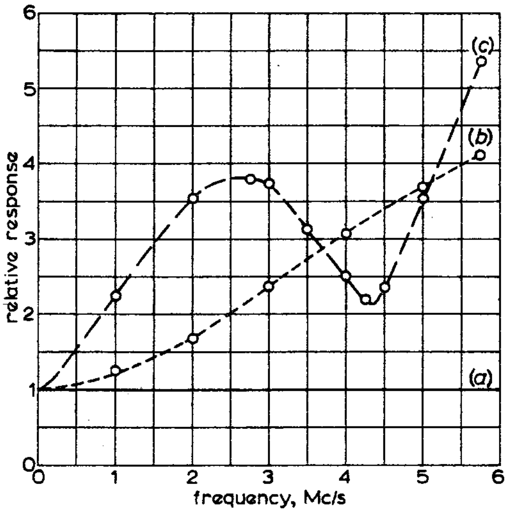

Fig. 4 - Frequency responses of distortion networks

(*a*) 'Flat' characteristic
(*b*) 'Top-lift' characteristic
(*c*) 'Notched' characteristic

Three types of distortion networks were used, each of which introduced a loss of 22 dB at zero video frequency. The frequency responses of the networks, shown as curves (*a*), (*b*), (*c*) in Fig. 4, will be referred to as 'flat', 'top-lift' and 'notched' respectively.

Before each test, the picture monitor was set up according to the following procedure, adopted as standard by Research Department for colour signal displays. Using a 'colour-bar' input signal, and with the 'red' and 'green' guns of the display tube switched off, the 'hue' and 'saturation' controls were adjusted to produce equal brightness of the four blue bars. Using a 'black-level' input signal, the 'brightness' control was adjusted to make the raster just imperceptible. Finally, using a monochrome 'Test Card C' input signal, the 'contrast' control was adjusted to give a peak picture brightness of 18 ft-Lamberts.

For each test, the viewers were seated 5 ft to 8 ft (i.e. about 4 to 6 times picture height) from the picture monitor and were asked to judge a set of displays. For the first display an undistorted picture was shown in order to familiarize the viewers with its appearance. To each subsequent display a delayed image was added at one of several levels, chosen in random order. Between displays the picture was removed so that each display presented a new condition to the viewers.

For preliminary tests, the viewers were asked to decide whether or not the delayed image was visible. For the final tests, the viewers were asked to grade the visibility of the delayed image according to the scale:

1. Imperceptible

2. Just perceptible

3. Definitely perceptible but not disturbing

4. Somewhat objectionable

The result for each display is expressed as the average of the grades selected by the panel of viewers. Grade 1·5, for example, means that the average assessment was midway between 'imperceptible' and 'just perceptible'.

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4.3.3. Results of Subjective Tests

Preliminary tests using a colour-bar signal and the 'flat' distortion characteristic showed that the most demanding condition occurred when the delayed signal was in anti-phase with the primary signal at zero video frequency, and in quadrature with the primary signal at the chrominance sub-carrier frequency. Those phase relationships were therefore adopted throughout the tests.

Further preliminary tests showed the most stringent colour slide (from a selection of about 30 slides) to be the S.M.P.T.E. colour test slide 'Girl in straw hat with flowers on hat' (EBU No. USA6), shown in monochrome form in Fig. 5.

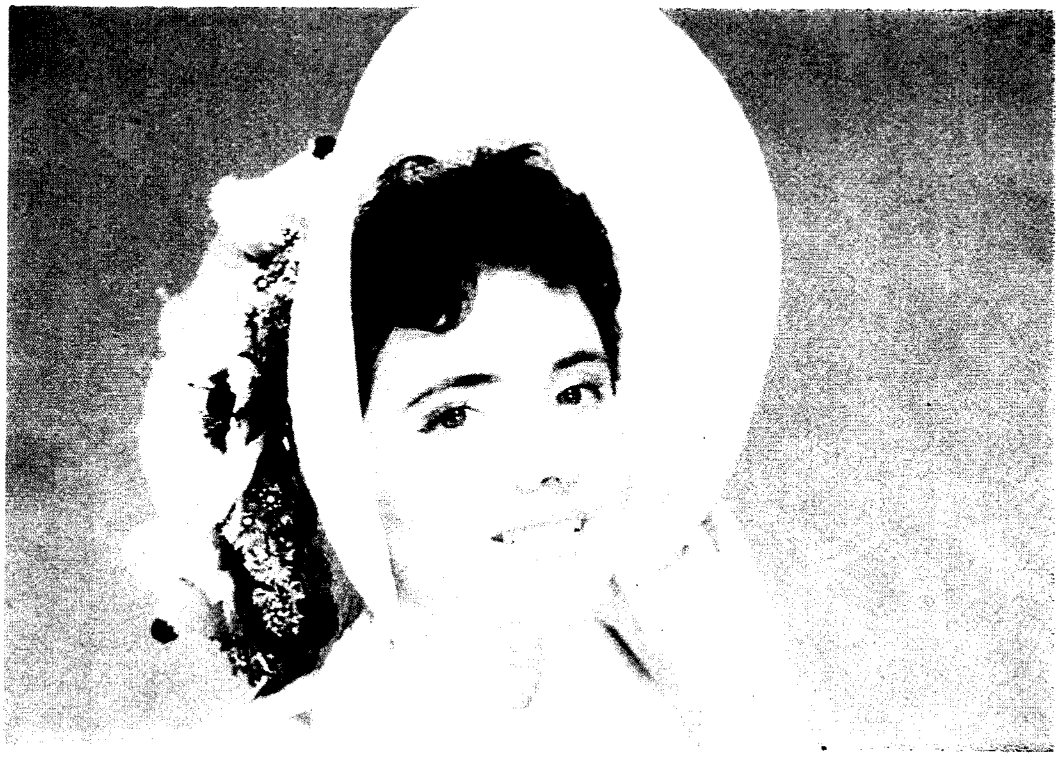

Fig. 5 - Slide used for subjective results shown in Figs. 6 and 7

Using the 'flat' distortion network, the average subjective grades (see Section 4.3.2) allotted by a panel of five viewers for various levels of delayed signal are given in Fig. 6. The results are in good agreement with those for long-delay reflexions shown in Table 2, since a delayed signal with amplitude about 1·25% of that of the primary signal (-38 dB) was graded 1·5 (i.e. was imperceptible to 50% of the viewers).

It became apparent when using 'top-lift' or 'notched' distortion characteristics that the visibility of delayed images could be governed by the levels of delayed signal at frequencies near to the luminance and chrominance carrier frequencies. On the other hand, the results of Fig. 6 were found to have been due almost entirely to interference with the luminance signals; interference with the chrominance signals became apparent at a much higher level of delayed signal. Accordingly, the shapes of

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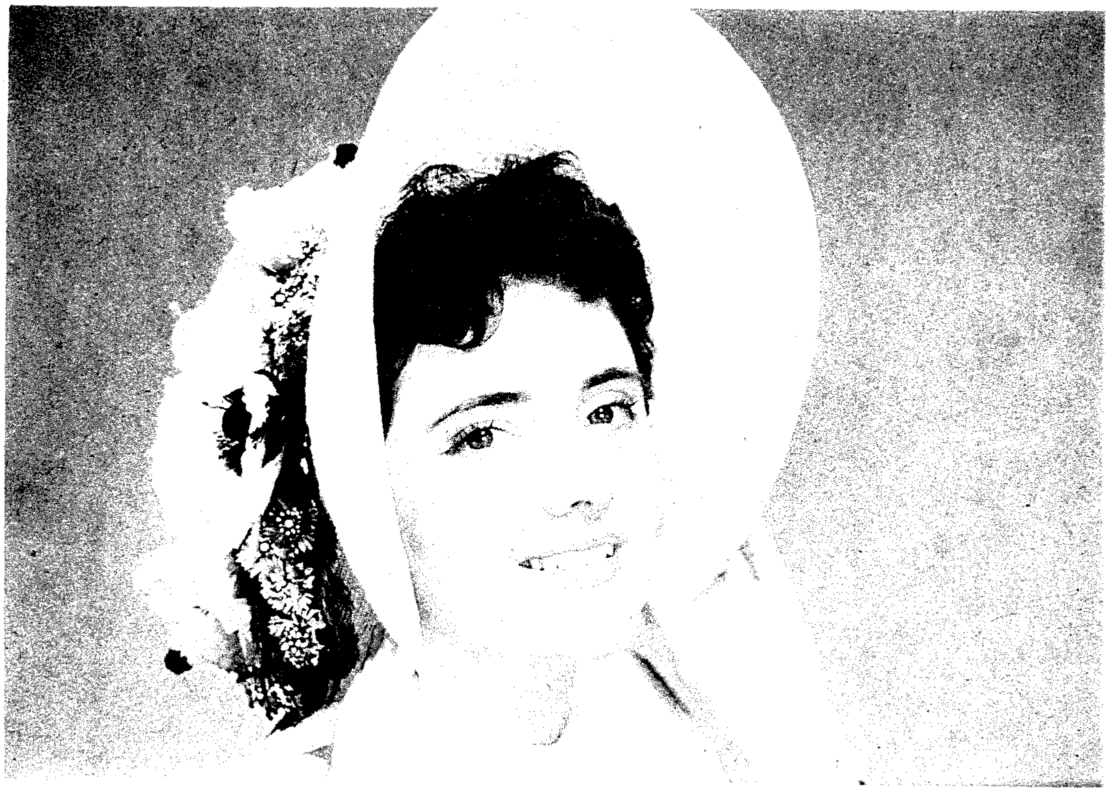

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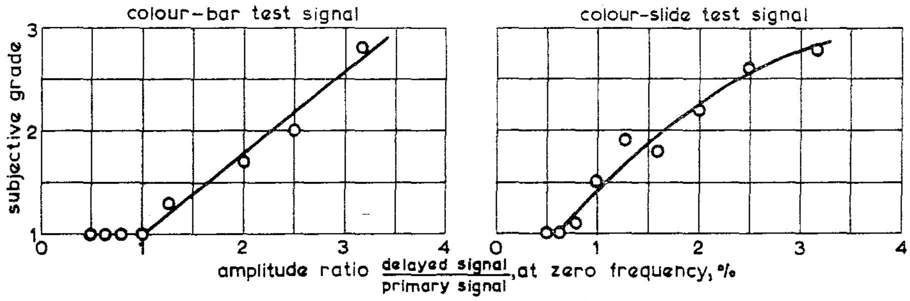

Fig. 6 - Visibility of delayed images: 625-line NTSC colour system
Average assessments of five observers
'Flat' characteristic delayed signal

the 'top-lift' and 'notched' characteristics were chosen not only with a view to providing the type of relaxation most suitable for an aerial impedance specification but also, so far as could be judged from the results of further preliminary experiments, to cause equal interference with the luminance and chrominance signals. Thus, for the final tests, the 'top-lift' and 'notched' characteristics shown as curves (*b*) and (*c*) in Fig. 4 were adopted. The average subjective grades allotted by a panel of five viewers for various levels of delayed signal, modified according to those characteristics, are given in Fig. 7.

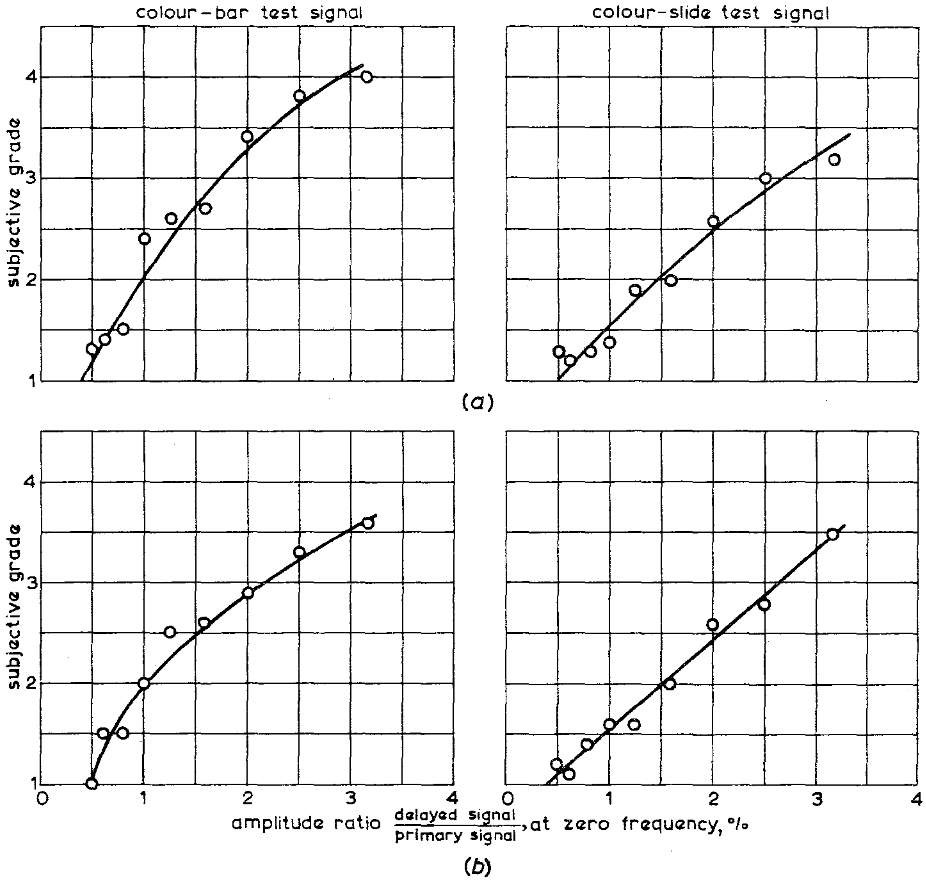

Fig. 7 - Visibility of delayed images: 625-line NTSC colour system
Average assessments of five observers
(*a*) 'Top-lift' characteristic delayed signal (see Fig. 4)
(*b*) 'Notched' characteristic delayed signal (see Fig. 4)

The results of Figs. 6 and 7 were obtained using colour bars, and the colour slide shown in monochrome form in Fig. 5, as the primary signal. Further tests showed the remaining slides, and moving pictures obtained from a video tape recorder, to be far less stringent.*

4.3.4. Resulting Specification

The results shown in Figs. 6 and 7 enable the maximum permissible levels of delayed signal to be specified but, before doing so, it must be borne in mind that those results were obtained under the following conditions, all of which were chosen so as to make the delayed signal most visible:

(i) The phase of the delayed signal was adjusted to cause the maximum interference with the luminance signal.

(ii) The delay was adjusted so that the phase of the delayed signal at the frequency of the chrominance sub-carrier caused the maximum interference with the chrominance signal.

(iii) The picture content of the primary signal was chosen in order to make the interference most visible.

It therefore seems reasonable to specify maximum levels of delayed signal which would, under such adverse conditions, be 'just perceptible' to 50% of experienced viewers (i.e. grade 1·5 in Figs. 6 and 7). Considering the results using both colour bars and the colour slide leads to a specification requiring, at the luminance carrier frequency, a 'flat' delayed signal not exceeding 1·25% or a 'top-lift' or 'notched' delayed signal not exceeding 1%. The corresponding levels at other frequencies over the upper sideband, obtained from Fig. 4, are given in Fig. 8. As shown previously

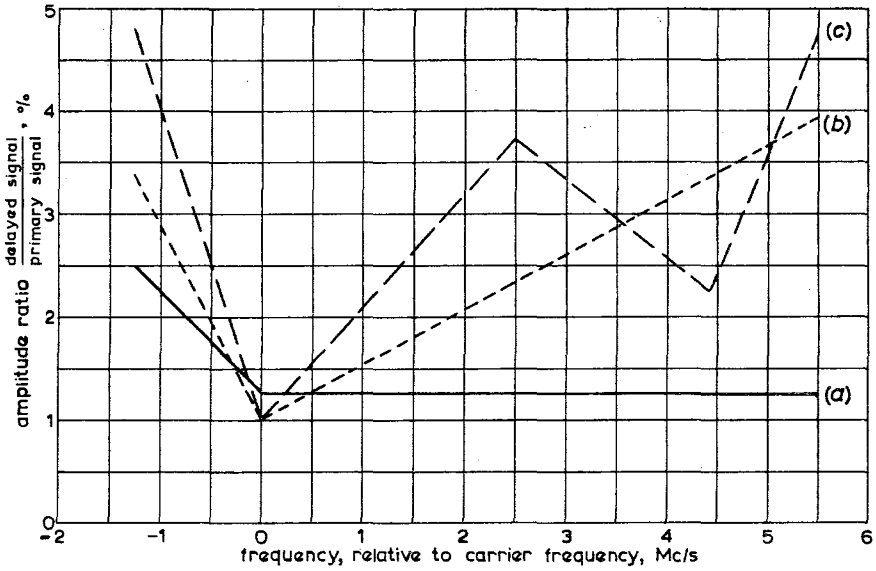

Fig. 8 - Percentage delayed signal: 625-line colour system

(*a*) 'Flat' characteristic (*b*) 'Top-lift' characteristic
(*c*) 'Notched' characteristic

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* It is likely that the content of the moving pictures that were available for these tests was not the most stringent that could have been chosen. Nevertheless, it is believed that, for the very low levels of delayed signals considered in this report, moving pictures would generally prove less stringent than stationary images.

for monochrome transmissions,[1] the level of delayed signal associated with a vestigial sideband channel may be allowed to increase linearly over the bandwidth of the vestigial sideband so that at -1·25 Mc/s relative to the luminance carrier frequency it is twice the value at +1·25 Mc/s.

The 'flat' specification shown as curve (*a*) of Fig. 8 is appropriate when specifying the impedance characteristic of multi-channel u.h.f. aerials or when specifying the levels of delayed signals caused by reflexions from distant obstacles such as masts or high buildings. The 'top-lift' or 'notched' specifications (curves (*b*) and (*c*) of Fig. 8) may be more appropriate for v.h.f. or two-channel u.h.f. aerials. The specifications may be applied to particular installations as shown in Section 6.

5. REFLEXIONS DUE TO FEEDER IRREGULARITIES

Reflexions due to irregularities in the feeder must be considered, particularly at u.h.f. The spacing between self-evident irregularities such as insulators is carefully chosen by the cable manufacturers so that their effect is not cumulative over the working range of frequencies. Nevertheless, other irregularities inevitably occur and, because the cables are made by machine, the irregularities may be uniformly spaced and their effect could become cumulative at frequencies within the transmission band. Several types of irregularity usually exist, each with different periodicity, causing sharp maxima of reflected signal to occur at closely-spaced frequencies. Their effect on a television picture display is to cause a succession of very low level delayed signals which individually are negligible, and the cumulative effect of which is usually very small.

Whilst cable manufacturers will generally supply detailed information once a particular sample of cable has been selected, their catalogues usually quote only the maximum reflexion coefficients that have been measured under steady-state conditions, with little or no information as to how the reflexion coefficient **varies** with frequency. In the majority of cases, therefore, it is impossible, a priori, to predict the precise effective reflexion coefficient of a given sample of cable. The following remarks are intended as a guide to specifying a cable such that its reflexions, together with those from the aerial, will cause negligible degradation to the picture.

For monochrome signals, experience at v.h.f. has shown that it is reasonable to specify a cable such that, measured under steady-state conditions, the reflexion coefficient due to its irregularities does not exceed 5% at any frequency in the working band provided that, if it were measured under pulse conditions using a signal at the vision carrier frequency modulated by 2T pulses,* its reflexion coefficient would not be likely to exceed 1%. Similarly, for colour signals it is considered reasonable to specify that the reflexion coefficient should not exceed 5% at any frequency in the working band, when measured under steady-state conditions, and should be less than 1% and 2% when measured under pulse conditions using a carrier (at the luminance and chrominance carrier frequencies respectively) modulated with 2T pulses.

* i.e. sine-squared pulses having a half-amplitude duration equal to the reciprocal of the system bandwidth.[7]

The reflexion coefficient of the cable is specified largely in terms of its pulse response because, for the type of picture degradation caused by cable irregularities, the response obtained under pulse conditions is generally much more meaningful than the steady-state response. On the other hand, the reflexion coefficient of the aerial is specified in terms of its steady-state impedance characteristic because not only is it a parameter which can easily be measured accurately but it also does not involve the use of a long cable.

6. APPLICATION TO PRACTICAL INSTALLATIONS

The levels of delayed signals specified in Tables 1 and 2, in Figs. 1, 2 and 8, and in Section 5 are the maximum levels of delayed signal that may be radiated from the aerial. In order to deduce the reflexion coefficients of the aerial and feeder system that would cause those levels to be radiated, allowance must be made for the loss in the feeders and combining filters, and for re-reflexion either at the transmitter or at some absorbing load. These factors afford relaxations and it is convenient to deal separately with their application to the aerial and the feeder specifications.

6.1. The Aerial Impedance Specification

6.1.1. The Effect of Loss in the Feeder and Combining Filters

Since the signal reflected from the aerial makes two traversals through the feeders and filters, a relaxation equal to twice their loss may be allowed on the aerial impedance specification.

6.1.2. The Effect of Loss in Re-reflexion at the Transmitter

Tests carried out in Band I at Holme Moss[1] showed the re-reflexion loss at a high-power modulated output stage to be about 1·5 dB; more recently, tests conducted by Planning and Installation Department on one of the u.h.f. sound transmitters at Crystal Palace, and by Research Department on one of the u.h.f. vision transmitters at Sutton Coldfield, showed that a similar loss occurs in the case of a klystron output stage. This loss, plus that due to an isolator or circulator, if one is fitted, may be applied as a relaxation to the aerial impedance specification.

Certain feeding arrangements have been suggested with a view to reducing the effective reflexion coefficient of the transmitter, and hence to increasing the relaxation applicable to the aerial impedance specification. They should be adopted with caution, however, because they may cause the delayed signal to be radiated with a vertical radiation pattern (v.r.p.) which is different from that of the primary signal; the relative level of the delayed signal may be satisfactory over most of the service area but high levels of delayed signal may occur near to the aerial. The effect occurs, in general, where reflected signals are radiated in cancelling phase in certain directions (usually towards the horizon) rather than being directed to an absorbing load. It is outside the scope of this report to consider this aspect in detail, but it will be discussed in relation to certain typical single-channel installations so that it may be borne in mind when framing the impedance specification, particularly where reception near to the aerial is important.

The simplest feeding system, involving a single transmitter and feeder, is shown block-schematically in Fig. 9(*a*). In this case a relaxation equal to the re-reflexion loss at the transmitter is allowed on the impedance specification.

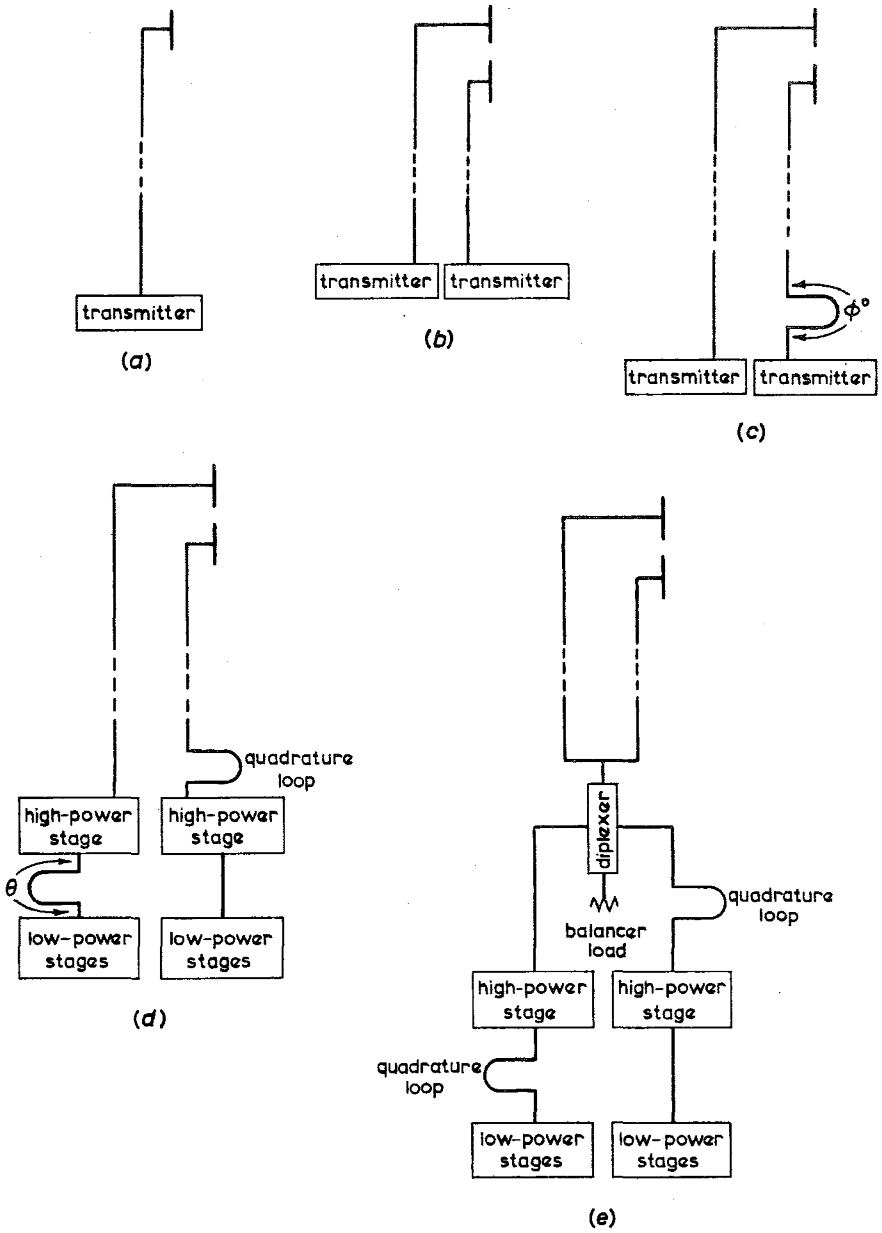

Fig. 9 - Typical feeder and combining systems

Note: Sound transmitters, vestigial-sideband filters, and sound/vision combining units have been omitted for clarity

(*a*) Single transmitter and feeder
(*b*) Split transmitter and aerial system
(*c*) Split transmitter and aerial system with beam tilt
(*d*) Split transmitter and aerial system with or without beam tilt
(*e*) Combined transmitters and aerial systems without beam tilt

Fig. 9(*b*) shows the general arrangement adopted at most existing BBC v.h.f. television stations. If the two halves of the aerial are identical, the primary and delayed signals will be radiated with identical v.r.p.s and the relaxation is the same as that for the arrangement of Fig. 9(*a*). If different reflexions occur in the two halves of the aerial, or if the feeds to the two halves are differently phased, the two v.r.p.s will be different. One particular case is shown in Fig. 9(*c*) where, to achieve beam tilt, the feed to the lower half of the aerial is retarded by ϕ° relative to the feed to the upper half. This arrangement could allow the aerial impedance specification to be somewhat relaxed since, if ϕ lies between $\pi/4$ and $3\pi/4$ (and particularly if $\phi = \pi/2$), the delayed-signal radiation from the two halves of the aerial will tend to cancel at great distance. Alternatively, whether or not beam tilt is required, cancellation at great distance may be achieved by inserting a quadrature loop at the output of one transmitter together with a loop of appropriate length in a low-power stage of the other transmitter,[5] as shown in Fig. 9(*d*). It should be noted, however, that both these arrangements simply re-distribute the delayed-signal power over the service area, and that, whilst the power may well be less over the greater part of the service area, it may be excessive near to the aerial. The additional relaxation that may be applied to the aerial impedance specification due to the artifice shown in Figs. 9(*c*) and 9(*d*) therefore depends upon the importance of providing a good service near to the aerial.

If the outputs of the two transmitters are combined before being fed to the aerial, the primary and delayed-signal v.r.p.s are identical. Furthermore, a balancer load can be incorporated, as shown in Fig. 9(*e*), such that signals reflected from the two halves of the aerial are completely absorbed provided their reflexions are identical and that the two transmitters re-reflect them identically.[6] The consequent relaxation to the aerial impedance specification would, at first sight, be considerable but, in practice, it would also be governed by the level of delayed-signal radiation that would occur during emergency conditions should one of the transmitters fail. For such emergency conditions it would be reasonable to restrict the level of delayed-signal radiation to -26 dB relative to the level of the primary signal; this implies that the feeder arrangement of Fig. 9(*e*) permits 12 dB more relaxation to the aerial reflexion-coefficient specification than would be permitted, for example, by the arrangement of Fig. 9(*b*).

6.2. Specification of Reflexions due to Feeder Irregularities

6.2.1. Relaxation Applicable to Split-Feeder Istallations

Although the two cables of a split-feeder installation (Figs. 9(*b*) to 9(*e*)) may be made on the same machine and therefore may have similar irregularities, it is unlikely that their reflexions will be identical, and still more unlikely that the cables would be cut so as to bring their reflexions in additive phase.

Based on their experience with television links, MacDiarmid[7] and Lewis[8] suggest that n unrelated delayed signals, each of relative amplitude 1%, are likely to give the same subjective effect as a single delayed signal of relative amplitude $n^{1/2}$% because the signals add in a random rather than a systematic manner. This was borne out in practice when tests were performed using four signals of differing delays, applied simultaneously.[1] Reflexions occurring in the two feeders of a split-feeder system, whether the feeders are connected to separate transmitters as shown in Figs. 9(*b*) to 9(*d*), or whether they are paralleled at ground level as shown in Fig. 9(*e*), will add in a random manner; thus, for the overall level of reflexions occurring in the two feeders combined to satisfy the requirements of Section 5, a relaxation of 3 dB is reasonable for the level of reflexions in each individual feeder.

6.2.2. The Effect of Loss in the Feeder and Combining Filters

A relaxation equal to twice the loss in the filters may be allowed on the permissible level of reflexions occurring in the feeders but, since the level of reflexions due to irregularities in each feeder is measured at its lower end, a further relaxation equal to the loss in only one traversal of the feeder may be allowed.

6.2.3. The Effect of Loss in Re-reflexion at the Transmitter

A relaxation of 1·5 dB due to re-reflexion at the transmitter may be allowed, plus a further relaxation equal to the attenuation of an isolator or circulator if one is fitted.

6.3. Example Specification

As an example of the manner in which these relaxations are applied in a particular case, the specifications for the feeders and for a two-channel aerial intended for colour transmission at a typical high-power u.h.f. station using the arrangement shown in Fig. 9(*b*) would be derived as shown in Sections 6.3.1 and 6.3.2.

6.3.1. Relaxations Applicable to the Aerial Reflexion Coefficient

Loss due to feeder attenuation (1000 ft feeders, two traversals)	4·4 dB
Loss in vestigial-sideband and combining filters say	1·0 dB
Loss due to re-reflexion at transmitter	1·5 dB
Total relaxation	6·9 dB

The reflexion coefficient that would be permissible at the junction of the aerial and the main feeder is therefore greater by a factor of 2·2 (6·9 dB) than the levels of delayed image specified in Fig. 8. The resulting specifications are shown in Fig. 10.

6.3.2. Relaxations Applicable to Feeder Irregularities

Loss due to feeder attenuation (1000 ft feeders, one traversal)	2·2 dB
Loss in vestigial-sideband and combining filters say	1·0 dB
Loss due to re-reflexion at transmitter	1·5 dB
Relaxation due to the use of two feeders	3·0 dB
Total relaxation	7·7 dB

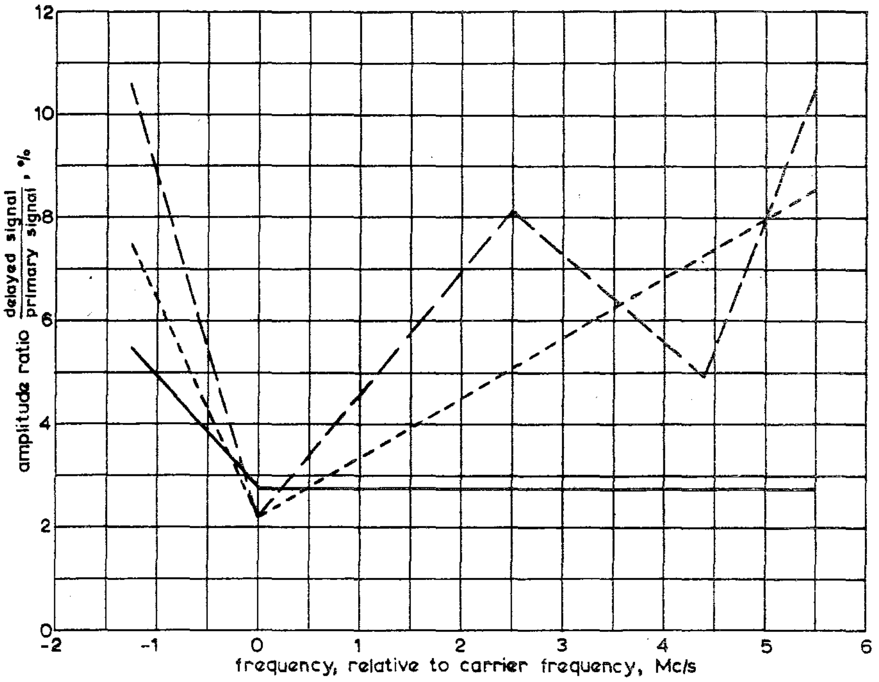

Fig. 10 - Alternative specifications for the reflexion coefficient of an aerial radiating colour signals at a typical high-power u.h.f. television station

If the reflexion coefficient of the aerial is plotted against frequency the curve must lie wholly below one of the three lines shown

The levels of reflexions permissible in the feeders would therefore be 2·4 (7·7 dB) times greater than those specified in Section 5.

7. CONCLUSIONS

Partly by extending the results of earlier work and partly as a result of recent investigations, the maximum permissible levels of delayed signals for 405-line and 625-line monochrome and colour television systems have been specified. Whilst the latter specifications are based on results obtained using colour signals of the NTSC type, they may be taken as satisfactory also for signals coded according to the standards of PAL or SECAM.

Specifications have been chosen which give equally acceptable pictures, but which lead to impedance specifications for transmitting aerials that are likely to be more easily met than those setting a uniform limit to the reflexion coefficient over the signal bandwidth. For instance, the shape of Fig. 8, curve (*b*) may be the most suitable for a two-channel u.h.f. aerial, whereas the shape of Fig. 8, curve (*c*) may be preferred for a single-channel v.h.f. aerial transmitting colour signals.

The specifications of Figs. 1, 2 and 8 refer to the maximum levels of delayed-signal radiation. Interpretation of these characteristics in terms of the reflexion coefficient at the junction between the aerial system and the main feeder depends upon the attenuation in the feeder and filters, and upon the reflexion coefficient at the transmitter. These are relaxations which are applied as described in Section 6; the resulting specifications in a typical case are as shown in Fig. 10.

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